2684

APPLICATION OF SOIL REMEDIATION TECHNOLOGIES IN THE GREATER TORONTO AREA

AUGUST 1993

Ontario

Ministry of Environment and Energy

09/08/93

ISBN 0-7778-1785-3

APPLICATION OF SOIL REMEDIATION TECHNOLOGIES IN THE GREATER TORONTO AREA (GTA)

AUGUST 1993

Cette publication technique
n'est disponible qu'en anglais.

PIBS 2684

APPLICATION OF SOIL REMEDIATION TECHNOLOGIES IN THE GREATER TORONTO AREA (GTA)

Report prepared by:

Science & Engineering Section
Waste Management Branch
Ontario Ministry of the Environment and Energy

APPLICATION OF SOIL REMEDIATION TECHNOLOGIES IN THE GREATER TORONTO AREA (GTA)

TABLE OF CONTENT

LIST OF TABLES

TABLE OF ACRONYMS

CCIW	Canadian Centre for Inland Waters (Burlington, Ont.)
CCME	Canadian Council of Ministers of the Environment
CoSTTeP	Contaminated Sediment Treatment Technology Program
DESRT	Development and Demonstration of Site Remediation Technology
GASReP	Groundwater and Soil Remediation Program (CCIW)
GTA	Greater Toronto Area
HC	Hydro Carbon
LT	Less Than
MAH	Mono Aromatic Hydrocarbon
NCSRP	National Contaminated Sites Remediation Program
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Poly Chlorinated Biphenyl
PCDD	Poly Chlorinated Dibenzo Dioxin (dioxin)
PCDF	Poly Chlorinated Dibenzo Furan (furan)
PCP	Poly Chlorinated Phenols (also Penta Chloro Phenol)
PID	Port Industrial District (Toronto harbour front)
RD&D	Research, Development and Demonstration
SEDTEC	Sediment Treatment Technologies Database (WTC)
SITE	Superfund Innovative Technology Evaluation (USEPA)
SVOC	Semi Volatile Organic Compound
TCE	Tri Chloro Ethylene
THC	Toronto Harbour Commissioners
TOC	Total Organic Compound
Ton	Short US ton (2,000 pounds, 907 kilograms)
Tonne	Metric tonne (1,000 kilograms, 2,204 pounds)
USEPA	United States Environmental Protection Agency
VISITT	Vendor Information System for Innovative Treatment Technology (USEPA)
VOC	Volatile Organic Compound
WPCP	Water Pollution Control Plant
WTC	Wastewater Technology Centre (Burlington, Ont.)

EXECUTIVE SUMMARY

This document presents a review of soil remediation technologies and a summary of processes which have been demonstrated on a commercial scale and which could be applied to site remediation in Ontario. Cleanup levels required under provincial/federal legislation are summarized.

Ontario cleanup criteria for inorganic contaminants are defined in the Ontario Decommissioning Guidelines (MOE, 1990). These guidelines are undergoing a major review under the development of a Materials Management Policy. Cleanup levels for organic contaminants are under development through the CCME, with MOEE participating actively (CCME, 1991).

Solid waste materials (soils from industrial/commercial sites, lake sediments) in the GTA have a wide range of contaminants and concentrations. Organics measured at sites affected by petroleum industries and related services range typically between 10 and 100 ppm per organic, with extremes up to 6000-8000 ppm. For other industrial sites, metal concentrations are typically near 100 ppm.

This document is limited to the summary of demonstrated processes. Demonstrated processes are those that have been demonstrated at a pilot or full-scale operation and whose conclusive results have been reviewed by the Ministry of Environment and Energy (MOEE). Commercial viability (cost evaluation and service availability) must also be documented.

There are numerous processes demonstrated commercially, and available from U.S. and Canadian companies. There are, however, more processes currently under development, and even more are emerging technologies / processes (i.e. at the stage of bench and laboratory testing). Processes are usually specific to remediation of either organic or inorganic contaminants. Certain other processes may be developed for specific sites. Some processes may include multi-phase treatments, where a combination of technologies are used.

Soil washing and volatile organic desorption are the most frequent technologies used for organic remediation. Metal extraction and stabilization (solidification) are the most common technologies used for inorganic remediation. Costs range in the order of $50 (Canadian) to $500/tonne for organic remediation, and CND $80 to $250/tonne for inorganic remediation.

Soil bioremediation, although used widely in warm climates (e.g. USA), has had limited success in Ontario. Additional research in this area is needed to tailor this technology to our climatic conditions, and to understand microbial degradation processes under various contaminant and soil conditions.

INTRODUCTION

The objective of this document is to present a review of soil remediation technologies and a summary of selected soil remediation processes which have been demonstrated as commercially viable, and which can be used at GTA sites. In this document, we make a distinction between "technologies" and "processes": a developer usually takes a specific technology (e.g. soil vapour extraction) and develops a specific application as a process (e.g. AquaDeTox). Processes are often referred to under registered trade names.

The document is divided into 4 chapters. Chapter 1 reviews the different types of soil remediation technologies, and their limitations. Chapter 2 reviews the processes demonstrated for remediation of the types of contaminated soil identified in the GTA. Chapter 3 discusses the technologies that could potentially be used in the remediation of GTA sites. In the same chapter, criteria for cleanup requirements are reviewed for Ontario compliance. Chapter 4 identifies present emerging technologies being researched and the need for further research, development and demonstration (RD&D).

1. REVIEW OF SOIL REMEDIATION TECHNOLOGIES

Remediation of contaminated soil is done using one of the two major groups of technologies: remediation for organic contamination and remediation for inorganic (metals) contamination.

Organic remediation relies on the fact that organics can either be volatilized from the soil, or destroyed by biodegradation, oxidation or thermal destruction (incineration).

Inorganic remediation generally involves either removal of the metals, or in rare occasions volatilisation.

Both types of contaminants (organics and inorganics) can be stabilized and/or solidified and made less mobile and less available for leaching. Stabilisation and solidification technologies are more efficient however for inorganic contaminants.

Another classification of soil remediation technologies refers to either **ex situ** remediation or **in situ** (MOE, 1992). Ex situ remediation requires that the soil be excavated, sometimes stock piled at the site and treated, or removed from the site and transported to a suitable treatment site. During in situ remediation, the contaminated soil is treated in place without being excavated.

In situ treatment requires that the remediation agents (air, chemicals, solvent, biomass or nutrient) be injected in the soil.

1.1 Organic remediation

Organic remediation technologies are frequently used because of the large number of sites contaminated with petroleum products (gasoline or fuel oil). Among these technologies, bioremediation is the most economical, although it may not be the most efficient and rapid. Other organic remediations include low temperature thermal desorption (LTTD), high temperature thermal destruction, chemical extraction, soil vapour extraction, air sparging and soil flushing.

1.1.1 Bioremediation

Bioremediation is a process by which the organic contaminants are destroyed by the action of the naturally occurring soil bacteria or by artificially added bacteria. Some bacteria are capable of obtaining energy by breaking down organic compounds such as petroleum hydrocarbons and converting them into byproducts such as carbon dioxide and water. Bioremediation can be applied either in situ or ex situ, and can take place aerobically (with oxygen present) or anaerobically (without oxygen).

In the context of soil remediation, several words with a prefix "bio" have been used to describe the action of microorganisms:

biodegradation: process of decomposition of contaminants by bacterial action

bioreclamation: use of bacteria to destroy contaminants in-situ to reclaim contaminated soils or groundwater

biorestoration: removal of contaminants in the soils to acceptable levels in order to restore the site to previous use

biotransformation: change or conversion of toxic contaminants into innocuous forms through the use of bacteria

biotreatment: use of bacteria to destroy contaminants in the soil

biostimulation: addition of nutrients, moisture and/or bacteria to enhance bacterial activity for destroying contaminants in the soil

Bioremediation involves the stimulation of growth and activity of these microorganisms in the contaminated soil sometimes by adding oxygen and nutrients. The factors considered important in the success of this technology focus on 3 elements (Beak, 1992): characteristics of the contaminant, soil, and microorganisms. The following presents some of the major consideration but appropriate references need to be accessed for details.

1) Characteristics of the contaminant:

Attributes:

Unless the chemical has been documented to be biodegradable (e.g. benzene, toluene, xylene), there are various chemical attributes that would indicate if the contaminant is susceptible to biodegradation. The increasing complexity of the **chemical structure** (chain type and length, molecular weight, substituents (NO_2, OH), and halogenation) generally means a decrease in biodegradability. A high **solubility** of the contaminant is favourable since the contaminant uptake is through the cellular membrane. **Volatilization** of the contaminant reduce the amount available as nutrient for the bioremediation process. Easy **sorption** of the contaminant to various materials in the soil generally has a negative effect on biodegradation. **Chemical reactions** between the contaminant and the medium may also effect the nutrient availability for the microorganisms or may even reduce the contaminant itself.

Biodegradability

In the assessment of the biodegradability of a contaminant, it is important to be familiar with the **classes of compounds** which are biodegradable, the **metabolic pathways**, the concept of **threshold concentration**, knowledge of the **kinetics and biodegradation rates**, and **toxicity** of the contaminant towards the microorganisms. In the absence of this knowledge, treatability studies should be undertaken.

Distribution

The identification of the **source** of the contaminant may identify "hot spots" which will determine the feasibility of the bioremediation project. The estimate of the **contaminant mass** will also be used in the assessment of the duration and the cost of the bioremediation project.

2) Physico-chemical characteristics of the soil:

Geochemistry

Most microorganisms prefer near neutral or slightly alkaline pH, with a general **pH tolerance** ranging from 5.5 to 8.5. The **redox potential (Eh)** (proportion of oxidized to reduced components in the soil) is also essential, since many enzymatic reactions (reactions within the microorganisms) are oxidation-reduction reactions.

All microorganisms have characteristic **temperature ranges** and optimums for growth and reproduction. For most bioremediation activities, the optimum temperature is between 20 °C and 30 °C. Higher temperature, if it does not kill the organisms, will result in higher metabolic activities (i.e. increased oxygen consumption). However, there can be significant microbial activities at temperatures outside this range: psychrophiles will tolerate temperature above 5 °C (optimum less than 15 °C) and thermophiles will tolerate temperature up to 60 °C.

Microorganisms must cope with **osmotic pressure** resulting from differences in solute concentration on opposite sides of their membrane. Although it is not a problem in general bioremediation projects, special microbial activities (such as reductive dechlorination) may result in increase of chloride ions and osmotic pressure.

Microbial activities in soil generally fluctuate with the **moisture content**: the lower the water content, the lower the activity. Tolerable moisture content ranges from 25% to 85%. Sudden change in the water content should be avoided, to ensure that waterlogging does not occur and that metabolism shifts from aerobic to anaerobic.

Inorganic **nutrients**, others than the ones provided by the organic contaminants, are also essential for the growth and maintenance of microorganisms. A ratio of 120:10:1 (C:N:P) is recommended for carbon, nitrogen and phosphate nutrients. Other inorganics such as sulphur, iron, magnesium, chloride ions and trace metals are also essential in low concentrations or at trace levels. Nutrients may need to be added at some sites.

Hydrogeology

Characterization of the hydrogeological environment is particularly important for **in situ treatment**, as it will assist in predicting the contaminant transport, nutrient distribution and microbial activity.

The **saturated zone** occurs below the watertable. Contamination of the saturated zone can consist of both soil contamination and/or groundwater contamination. The **unsaturated zone** (also referred as vadose zone) is the region extending from the ground surface to the upper surface of the first water formation. The vadose zone is in contact with the atmosphere through its network of pores, and is also in contact with the saturated zone through a capillary action. Contaminants in the vadose zone may adsorb to soil particles or may volatilize and be retained within the pore spaces.

Hydraulic conductivity (K) refers to the overall ability of a porous medium to conduct water. The variation of K values at the treatment site (injection of bioremediation elements, bioventing) is an essential parameter for in situ treatment. The direction and the magnitude of the **hydraulic gradient** control the movement of groundwater and associated contaminants. The **porosity** of the soil (percentage of void space in the soil) will determine the amount of liquid that may be retained in the soil. The **permeability** of the soil (ability of the soil to allow passage of liquid) will be key to the migration of contaminants.

3) Characteristics of the microorganisms:

The initial conditions of the contaminants and the contaminated soil will determine the group of microorganisms and nutrients to be used. The microbial community will change in size and composition during bioremediation as some organisms will flourish under specific site conditions while other organisms will die off. For a successful bioremediation, the following microbiological properties should be characterized.

The **biomass size** should be monitored as it should generally increase during active bioremediation and show variations between the contaminated and uncontaminated zones. The initial determination of the **microbial composition** will indicate if the appropriate degrading microorganisms are present. Analysis of the biomass and the microbial composition does not indicate however microbial activity. **Microbial activity** is indicated by

- may be difficult to attain required cleanup levels;
- large treatment area may be required;
- may contaminate the soil underneath the treatment area.

ENHANCED BIOREMEDIATION (COMPOSTING)

This is a process in which the bacterial action is accelerated by controlled treatment conditions with uniform distribution of water, oxygen and nutrients, chemicals for pH control, and temperature control. In some cases, a special culture of bacteria may be added along with soil amendments, such as nutrients, wood chips, sand.

Contaminated soil is placed in a large pile over a number of perforated pipes laid out in parallel. The pile is sprinkled with a mixture of water, surfactants and fertilizer. The air is drawn through the pile by a vacuum pump connected to the piping. In some cases, large wood chips are added as a bulking agent to facilitate the flow of air through the pile.

Applicability

- soils contaminated with petroleum fuels (as gasoline, jet fuel, diesel);
- oil sludges;
- polycyclic aromatic hydrocarbons (PAHs including naphthalene, anthracene, etc.);
- benzene, toluene, ethylbenzene, and xylene (BTEX);
- some chlorinated solvents.

Potential Advantages

- minimum labour requirements;
- low costs;
- shorter time of treatment than landfarming;
- more positive control of air emission;
- soils with high contaminant levels can be treated.

Potential Limitations

- presence of heavy metals, chlorinated organics, pesticides, etc. can be toxic to bacteria;
- variable composition of soil may lead to inconsistent results;
- low levels cannot always be achieved.

growth (increase in cell numbers), nutritional status (utilisation and depletion of the contaminants), stress (leading to adaptation or acclimation of the organisms to a new site) and metabolic activity and capabilities. Finally the more homogenous the **microbial distribution**, the faster and more uniform the bioremediation will proceed.

Bioremediation can be applied in various forms: surface bioremediation, enhanced bioremediation, bioventing, or soil slurry bioreactor. These different application are reviewed in the following paragraphs.

SURFACE BIOREMEDIATION

Surface bioremediation is also called LAND TREATMENT or LANDFARMING and involves the tilling and the cultivating of the soils to encourage biological degradation of hydrocarbons.

Excavated contaminated soil is spread over a treatment area in a layer usually 15 to 30 cm thick. The treatment area is properly designed for positive drainage and is surrounded by a soil berm to prevent runoffs, and in some cases covered with a FML (flexible membrane liner). Agricultural fertilizer, water, bacteria, and lime are added, as required. The soil is cultivated with a tiller, disc harrow or some other farm equipment to mix the soil bacteria, air and nutrients. In some cases, a road grader is used.

Applicability

- petroleum hydrocarbon fuels (gasoline, diesel and heating fuels);
- oil sludges and tank bottoms;
- soils contaminated with polycyclic aromatic hydrocarbons.

Potential Advantages

- low to moderate costs;
- low labour requirements;
- can be effective on some heavier crudes.

Potential Limitations

- temperature dependent;
- presence of certain contaminants may be toxic to bacteria;
- air emissions control may be needed;
- may require large volumes of water to keep the soil moist;
- soil conditions may not be suitable (e.g. dense soils);

BIOVENTING

Bioventing is an in situ process where air is injected into contaminated soil, at a rate low enough to increase soil oxygen concentrations and stimulate indigenous aerobic microbial activity. In addition to oxygen, other nutrients (soluble nitrogen and phosphorous compounds) may be pumped into the soil through the injection wells, in amounts appropriate for optimizing the growth of microorganisms.

During bioventing, the soil surface is monitored to detect volatile organic compounds (VOC) emission. Such emission indicates that air is injected at too high a rate, and that VOCs do not have time to biodegrade before escaping at the surface.

Bioventing may be used in conjunction with soil vapour extraction, where extraction wells are used with the injection wells.

SOIL SLURRY BIO-REACTOR

The first step in this process is to separate and remove the larger soil particles. The soil is then mixed with water to obtain a slurry of proper consistency. The slurry is mechanically agitated in a bioreactor vessel to keep the solids suspended and to maintain an intimate contact with the bacteria. Suitable amounts of nutrients, water, surfactants and sugars are added to maintain proper levels of active biomass population in the bioreactor. Once the treatment is completed, the slurry is dewatered and the water is further treated and clarified and the clean soil is disposed of.

Applicability

- petroleum hydrocarbon fuels;
- chlorinated organic solvents;
- crude oil, oils and grease;
- PAHs;
- some pesticides.

Potential Advantages

- minimum labour requirements;
- treats higher levels of contaminants;
- a wide range of organics can be treated;
- less space requirements;
- air emissions can be controlled.

Potential Limitations

- presence of heavy metals, pesticides and chlorinated organics may be toxic to the bacteria;
- capital costs for equipment may be expensive;
- contaminants with low solubility are more difficult to treat;
- low cleanup levels are not always achieved;
- operating temperature must be 20° to 30° C.

1.1.2 LOW TEMPERATURE THERMAL DESORPTION (LTTD)

The contaminated soil is excavated, screened and heated in a closed chamber to temperatures ranging from 200°C to 260°C to volatilize the light organic contaminants. The off-gases from the soil are then passed through an air emission control system or a recovery system. In some cases, the gases are passed through to a second reactor and incinerated.

The basic components of the operation are:

- feeder with screening;
- rotary kiln with indirect infrared heating or indirect heat exchanger;
- air emission control;
- recovery system with activated carbon or afterburner.

Applicability

Soil contaminated with low volatilization temperature such as petroleum fuels (gasoline, jet fuel, diesel fuel) and some pesticides.

Potential Advantages

- volatilize a wider range of petroleum products than in-situ technologies;
- treatment can be accomplished in a short period of time;
- system is relatively compact and mobile.

Potential Limitations

- removes only volatile organic compounds (VOCs);
- precautions must be taken to avoid explosions within the equipment;
- high levels of metals (e.g. mercury), fluorides, chlorides, and sulphur may cause problems in the air emission controls;
- high moisture content may reduce efficiency;
- may not be suitable for soils with high percentage of clay and silt;

- may not be capable of handling soils with greater than one percent petroleum hydrocarbon content for some designs;
- chlorinated organics require more elaborate air emission control system.

1.1.3 HIGH TEMPERATURE THERMAL DESTRUCTION

This technology utilizes high temperatures in the range of 850 to 1200°C as the principal method of destroying organic contaminants. The treatment involves heating excavated soil in a closed chamber to volatilize and destroy organic compounds by converting them to carbon dioxide and water. The off gases are passed through a secondary chamber at higher temperatures to ensure complete destruction of all organic constituents and then through the air emission control system. The destruction and removal efficiency achieved in this treatment exceeds 99.9 percent.

The types of incineration equipment include:

- rotary kiln;
- fluidized bed;
- infrared thermal;
- pyrolytic.

Applicability

- practically any type of organic contaminant;
- not applicable for most metals.

Potential Advantages

- all organics are completely destroyed;
- Destruction and removal efficiency (DRE) is greater than 99.99% with most organic compounds.

Potential Limitations

- presence of halogenated organics may require special air pollution control equipment;
- production of volatile metals, PCB and dioxins;
- feed size limitations for some equipment;
- high fuel requirements;
- high capital costs for incineration equipment;
- high operating costs;
- permits may be difficult to obtain;
- treated soils may be sterile.

1.1.4 CHEMICAL EXTRACTION

Chemical extraction, also referred to as SOLVENT EXTRACTION or SOIL WASHING, is an ex situ process used to separate the contaminants into respective phase fractions: organics, water, inorganics and particulate soils. It involves mixing the soil with water or water containing a chemical extracting agent to release and remove the contaminant from the soil particles. The extracting reagent may be any one of the lixiviants (chemical reagent used to extract a soluble component from a mixture), such as a solvent, a surfactant, a chelating agent, an acid or a base. The reagent may dissolve, precipitate or separate the contaminant from the soil.

To be effective, soil washing must either transfer the contaminants to the wash fluids or concentrate the contaminants in a fraction of the original volume, using size separation techniques. In either case, soil washing must be used in conjunction with other treatment technologies, to clean either the washing fluid or the residues.

The resulting mixture is mechanically aerated, centrifuged or filtered to separate the extracting reagent with the contaminant from soil. The soil may be washed or aerated to remove residual extracting reagent. The recovered extracting agent is then filtered to remove particulates and treated to remove contaminants. Some extraction chemicals can be reused.

<u>Applicability</u>

With the use of appropriate extracting agents this process can effectively remove petroleum hydrocarbons and fuel residuals, heavy metals, pesticides, herbicides, PCB, cyanides, wood preservatives, and creosote.

Can be used to treat soils contaminated with acids, base and heavy metals and soils with high moisture content.

<u>Potential Advantages</u>

- wide range of applications.

<u>Potential Limitations</u>

- clay content greater than 20 to 30 percent;
- high level of volatile organic carbon may combine with the extracting agent;
- not all organic compounds can be removed effectively.

1.1.5 SOIL VAPOUR EXTRACTION

Soil Vapour Extraction (SVE) involves the removal of volatile organic contaminants from the subsurface soils (unsaturated zone) by forcing air through the soil matrix, and extracting the organic vapour at the surface.

A variation in the application of this technology involves injecting heated steam in the contaminated soil. Often called STEAM STRIPPING, this process extend the efficiency of the process by including organics not normally volatilized at normal temperature.

If contamination extends below the unsaturated zone (vadose zone) to the saturated zone, SVE is used in series with the air sparging method (reviewed in following sections).

The basic components of the system include:

- extraction well;
- induced air draft fan or vacuum pump;
- screened perforated pipes to direct air flow through the soil matrix;
- treatment unit such as an activated carbon filter to remove contaminants from the air emissions;
- monitoring system.

Applicability

- gasoline, jet and diesel fuels from unsaturated subsurface area;
- degreasing solvents.

Potential Advantages

- low costs;
- capable of removing hydrocarbon fuels from beneath buildings and paved areas without serious disruptions;
- low labour requirements.

Potential Limitations

- removes only volatile organic compounds;
- not effective for soils below water table;
- performance can be affected by soil conditions;
- removal efficiency determined by spacing and depth of vents.

1.1.6 AIR SPARGING

Air sparging is an in situ treatment technology that injects air into the saturated zone, forming bubbles that rise and carry trapped and dissolved contaminants into the unsaturated zone. Through a subsequent treatment by soil vapour extraction (SVE), the contaminants can be removed from the soil.

At the same time, a biodegradation mechanism may be present during air sparging. Aerobic biodegradation of contaminants by indigenous microorganisms requires the presence of carbon, nutrients and oxygen. Air sparging increases the oxygen content of the groundwater and thus enhances aerobic biodegradation. Certain organic contaminants, such as petroleum products, serve as a carbon source for naturally occurring microorganisms. The rate of biodegradation can be enhanced by optimizing the nutrient in the system.

The basic components of the system include:

- air injection well;
- air compressor
- screened perforated pipes to direct air flow through the soil matrix;
- monitoring system/well.

Applicability

- gasoline, jet and diesel fuels from saturated subsurface area;
- degreasing solvents.

Potential Advantages

- low costs;
- capable of removing hydrocarbon fuels from beneath buildings and paved areas without serious disruptions;
- low labour requirements.

Potential Limitations

- effective for soils below water table, when combined with soil vapour extraction in the unsaturated zone;
- removes only volatile organic compounds;
- performance can be affected by soil conditions;
- removal efficiency determined by type of soil: coarse grained soils (sand and gravel) are better than fine grained soils (silt and clay).

1.1.7 SOIL FLUSHING

Soil flushing (also referred to as SOIL LEACHING) is an in situ treatment technology which involves injecting or flushing the soil with a solution to leach out contaminants in the soil. For petroleum hydrocarbons, non-toxic or biodegradable surfactants are added to the water to improve solubility and possible recovery. For heavy metals and inorganic contaminants, chemical reagents are added to the water to modify its pH or to enhance the solubility of the contaminants. After the leaching, the solution laden with the contaminants is sent to an on-site treatment plant for the removal of the contaminant. The treated water can be reused.

Applicability

Depending on the type of leaching additives and soil characteristics, the following chemical contaminants can be leached out:

- heavy metals (lead, copper, zinc, chromium);
- halogenated solvents (trichloroethylene, perchloroethylene);
- aromatics (benzene, cresols, toluene, phenols, xylene);
- gasoline, fuel oils, diesel, crude oil;
- hydraulic and other viscous oils;
- PCBs and chlorinated phenols;

Potential Advantages

- low costs;
- minimum labour requirements;
- no need for excavation.

Potential Limitations

- difficult to confirm how well the objectives have been met;
- injection of some chemicals into the subsurface may not be acceptable;
- soil conditions must be ideal (e.g. low permeability clay type soils do not lend themselves to this technology);
- increased potential for contaminant migration beyond the affected area;
- large volumes of water and chemicals may be required.

1.2 Inorganic remediation

1.2.1 STABILIZATION / SOLIDIFICATION

The main purpose of this technology is to immobilize the contaminants in the soil for safe disposal or reuse. The process involves the addition of a sufficient quantity of materials that combine physically (solidification) and/or chemically (stabilization) to decrease the mobility of the contaminants in the soil.

Other purposes include:

- limit the solubility of contaminants in the soil;
- detoxify contaminants;
- decrease the surface area through which the transfer and loss of contaminant can occur.

Applicability

- soils contaminated with heavy metals;
- soils moderately contaminated with petroleum hydrocarbon fuels;
- soils moderately contaminated with refined petroleum products.

Potential Advantages

- raw materials are inexpensive;
- technology is well established and equipment is readily available;
- least expensive of the ex-situ technologies.

Potential Limitations

- restrictions may be imposed on future land use;
- long term integrity of solidified materials are not well established;
- no approved test protocols for long term leachability;
- presence of high levels of organics in the soil interferes with process.

1.2.2 CHEMICAL EXTRACTION

The same technology presented in Section 1.1.4 for organic treatment can be used for inorganics. The reagent is specifically selected to extract metals from the soil and then release them from the solution by either pH control and precipitation of metal oxides, or adsorption of metal complexes on adsorbing medium (e.g. resin).

1.2.3 VITRIFICATION

In-situ vitrification is a process by which the in-place contaminated soils are converted into a chemically inert stable glass and crystalline product through the use of electrical heat.

Four electrodes are inserted into the contaminated soil in a square pattern and a small quantity of a mixture of graphite and glass frit is placed in an "X" pattern on the soil surface. This provides a conductive path for the initial electrical current. When the electrical current is applied, heat is generated with the temperatures in the soil matrix reaching over 1,700°C. This causes the silica and aluminium oxides in the soil to melt. Any organic in the soil will be pyrolysed and resulting gases may combust at the surface when they come into contact with air. At the end of the specified time, all of the organics are destroyed. The electrodes are removed from molten mass which is allowed to cool into a vitrified mass entrapping remaining contaminants.

Applicability

Contaminated soils with a wide range of chemicals:

- heavy metals and plating wastes;
- inorganics (fluorides, nitrates, chlorides and sulphates);
- PCBs;
- high boiling organics (PCBs, PAHs, tank bottoms, petroleum-based oils, heavy fuel oils, tank bottoms;

Potential Advantages

- process can treat simultaneously soils contaminated with mixed classes of chemicals (both organics and inorganics);
- treated by-product is not likely to have any environment or health impact.

Potential Limitations

- cannot treat soils with high permeability;
- not suitable for soils located near groundwater and those with high organic content (over 10 percent);
- mercury will vaporize when exposed to vitrification temperatures;
- metal drums buried between electrodes may cause electrical short-circuit;
- soils with combustible liquids, low boiling liquids;
- depth up to 17 m.;
- expensive.

2. DEMONSTRATED SOIL REMEDIATION PROCESSES

2.1 Definition

Complex technologies are normally developed in 3 stages:

1) bench (lab) testing;
2) pilot plant testing;
3) full scale demonstration and process commercialization.

Once a vendor has tested and demonstrated that a technology can be used commercially, we refer to this technology as a process. Other vendors can also use that same technology (provided they do not infringe on patents), and after different tests and objectives, can develop a different process.

This document is limited to the review of soil remediation processes demonstrated on a commercial scale as defined below:

1) processes that have been submitted to pilot or full scale tests,

and where promising and/or conclusive results have been published and reviewed by Canadian agencies,

and where operation costs have been evaluated during the demonstration phase, and the process is commercially available from the proponent/vendor or a contractor;

or

2) processes that have been **accepted** for and have **completed** the Demonstration Program of the Superfund Innovative Technology Evaluation (SITE) program, under USEPA supervision (see next section).

2.2 Demonstration in Canada

There are a number of programs in Canada which support research or demonstration of soil remediation technologies. The projects of these programs are listed in the Chapter 4. In this section, demonstrated processes (as defined in section 2.1) are reviewed.

DESRT program

In October 1989, a 5-year ($250 million) National Contaminated Sites Remediation Program (NCSRP) was initiated by the Canadian Council of Ministers of the Environment (CCME) to deal with sites contaminated by hazardous wastes. A total of $200 million is

committed to cleanup "orphan" sites, and $50 million to the program of Development and Demonstration of Site Remediation Technology (DESRT).

The primary goal of the DESRT program is to work with industry to develop and test new methods for assessing and cleaning up contaminated sites (CCME, 1992). Proponents are invited to submit a demonstration proposal to both levels of government (provincial and federal). If the proposal is accepted at both levels, the project is funded at 50% (25% by each government) by the governments and 50% by the proponent. The report include a technical review of the demonstration, and an economic assessment of the commercialization of the technology.

A summary of the demonstrated technologies are presented in Table 1. Some projects involved more than one specific remediation technology. The demonstration of a properly selected combination of technologies is considered by DESRT as a new technology.

CoSTTeP program

The Contaminated Sediment Treatment Technology Program (CoSTTeP) is a demonstration program initiated by Environment Canada's Great Lakes Environment Office and administered by the Wastewater Technology Centre (WTC) where a sediment treatment technologies database (SEDTEC) is maintained (WTC, 1992).

A number of projects are still at the stage of bench testing, which is considered as emerging technology in this document. Only demonstrated projects at the pilot-scale or full demonstration levels are included in Table 2.

2.3 Demonstration in the U.S.A.

The USEPA demonstration program is part of the Superfund Innovative Technology Evaluation (SITE) program. The SITE program was developed in 1986 to promote the development and use of alternative and innovative technologies for Superfund sites (USEPA, 1986). "Alternative and innovative technologies" are defined to mean technologies that permanently alter the composition of hazardous wastes through chemical, biological, or physical means, in order to significantly reduce the toxicity, mobility or volume of the contaminants (Hill et al, 1991).

The program is therefore not limited to soil remediation technology, but includes wastewater and leachate treatment, and hazardous waste treatment. Soil remediation technologies identified and demonstrated in this program are presented in this document.

The SITE program includes a systematic evaluation process (USEPA, 1989), including the following programs:

1) Emerging Technology Program:

Before a technology is accepted into this program (through Requests for Pre-Proposals), sufficient research data must be available to validate its basic concepts. The program involves subjecting the technology to a combination of bench-scale and pilot-scale testing. The technology performance is documented in a report.

The technologies identified under the Emerging Technology Program are not considered as technology demonstrated commercially.

2) Demonstration Program:

If bench and pilot test results are encouraging, the technology may proceed (after authorization) to a field demonstration. In this program, the technology is field-tested on hazardous waste materials. Engineering and cost data are gathered to assess the technology applicability for site cleanup. The Demonstration (Technology Evaluation) Report presents information such as: testing procedures, sampling and analytical data, quality assurance/quality control and significant results.

Under the Demonstration Program, new technologies are reviewed and results of the program published in annual technological profiles (USEPA, 1989, 1991a) and in frequent demonstration bulletins (e.g. USEPA, 1992). A summary of these technologies (which have completed the Demonstration Program and which are applicable to soil, sediment or sludge remediation) is presented in the Table 3.

Table 3 does not include the numerous technologies currently at different stages of the demonstration program (site selection, pilot testing, data collection and report preparation). Some of the comments in the table are based either on the site demonstration reports or the VISITT database (see next section).

3) Technology Transfer Program

In this program, technical information on technologies is exchanged through various activities: SITE publications, reports, brochures, videos, public meetings, seminars, demonstrations SITE visits, exhibition, etc..

Information from VISITT

An information system has been set up by USEPA to help the distribution of new technologies. The VISITT (Vendor Information System for Innovative Treatment Technologies) was developed in 1991 by the USEPA (Technology Innovation Office) to provide current information on innovative treatment technologies (VISITT, 1992a). VISITT contains technology information submitted by developers, manufacturers, and suppliers of innovative treatment technology equipment and services.

However, USEPA is quick to point out that the inclusion of specific technologies in VISITT does not mean that the Agency approves, recommends, licenses, certifies, or authorizes the use of any of the technologies. Nor does the Agency certify the accuracy of the data. Inclusion means only that the vendor has provided information in early 1992 on a technology that USEPA consider to be innovative (VISITT, 1992b).

---

3. APPLICATION TO GTA SITES

The first objective of this document, as mentioned earlier in the introduction, is to identify demonstrated processes that could remediate contaminated soils to levels dictated by either the Ontario decommissioning guidelines or the interim CCME remediation levels. The task is not as simple as finding a process with an efficiency matching the remediation factor of the contamination and cleanup levels. There are a number of factors that may affect the efficiency of the demonstrated processes, such as the type of soil (fine or coarse), the moisture content, the composition of other contaminants in the soil, etc. The use of Tables 1, 2 and 3 may be, however, the first screening process which would allow a proponent to reduce the number of demonstrated technologies to a manageable group.

3.1 Ontario Remediation Levels

A number of decommissioning and cleanup criteria for inorganic contaminants are set in the Ontario decommissioning guidelines (MOE, 1990), and presented in Table 4. For comparison purposes, the interim inorganic remediation criteria developed by the Canadian Council of Ministers of the Environment (CCME, 1991) are also included in this table.

The Ontario decommissioning guidelines do not address the level of organic contaminants. Interim remediation levels for organics were, however, developed by CCME and these levels are frequently used in the development of cleanup programs in Ontario. A Materials Management Policy is under development in Ontario: one of the

purposes of the policy will be to classify any excess material under four material categories, leading to four management options. Until specific organic criteria are adopted in the Ontario guidelines, the CCME levels are considered interim levels in Ontario. Table 5 summarizes the main groups of organics.

3.2 Ataratiri Site

The Ataratiri site is a land area of approximately 32.4 hectares, adjacent to the West side of the Don River and South of Eastern Avenue. A summary of the numerous samples taken during the characterization of the site is presented in Tables 6 and 7.

Average inorganic levels are below decommissioning guidelines, although maxima are generally above these guidelines. The average concentrations for a number of organics (e.g. naphthalene, phenanthrene, PCDD/PCDF and PCB) exceed the residential CCME interim guidelines, without exceeding the commercial/industrial ones.

Remediation technologies suitable for inorganics would need an efficiency of near 98% for the maximum levels recorded for certain metals (zinc, copper, nickel and lead). Organic remediation would require technologies near 99.9% for treatment of maximum concentrations of naphthalene and PCB. For the average naphthalene concentration (23.9 ppm), an efficiency of 80% would be required to meet the CCME interim criterion of 5 ppm.

The site is essentially a landfill where various types of materials have been used over the past 80 years as fill and land reclamation from the lake front. Because of the heterogeneity of the soil, in situ bioremediation can be excluded. The most suitable technologies would be chemical extraction or high temperature thermal destruction (in order to treat larger organic molecules). Low temperature thermal desorption would be applicable only in areas where light petroleum products were the only contaminants present.

Since December 1992, Tallon Metal Technologies Inc. (Guelph) is conducting a pilot test on 35 tonnes of contaminated soil from the Ataratiri site. The Vitrokele (Trade Name) process uses chemical extraction technology, where a synthetic resin adsorbs heavy metals from the fine fractions of soil. Metals are later stripped from the resin and recovered. This process does not remediate the organics however.

3.3 Junction Triangle

The term "Junction Triangle" refers to an area located near the intersection of Bloor and Dundas streets, and enclosed by railway tracks forming a triangle. The area has a long history of industrial and commercial operations with numerous cleanup operations presently being conducted by individual industries.

In general the inorganic levels are below the decommissioning guidelines, except for some spots where zinc (Zn) has been measured at near 800 ppm. Levels of organics measured at the most contaminated sites are typically in the 100 ppm range, and can be as high as 800 ppm (the general range of interim remediation levels for organics is 5-50 ppm; see Table 2). Soil contaminated by petroleum products (e.g. diesel fuel and gasoline) could be as high as 6,000 ppm in certain areas.

Inorganic remediation technologies would require in general 95% efficiency. The same level of efficiency would be required also for treatment of organic contamination.

The types and levels of contamination are site specific, consequently we can only talk in general terms in this document. The type of soil in the area is generally clay in the northern parts and sandy-gravel type in the southern parts of the site. In situ treatment could be feasible in the southern areas, due to the type of soil. Other factors to consider are the type and concentration of the contaminants found at specific sites.

3.4 Port Industrial District

The Port Industrial District (PID) represents an area of some 300 hectares bounded to the north by Lakeshore Boulevard East, to the south and west by Lake Ontario and to the east by Leslie Street. The area has been under the management of the Toronto Harbour Commissioners (THC) since 1911.

In a recent decommissioning strategy study (Beak, 1990), the audit identified 4 main potential contaminants (metals, hydrocarbons, PCBs and PAHs) in 10 major land use categories ranging from residential to industrial applications. The type of soil varies from site to site, depending on the type of fill materials used in the reclamation of the lakeshore. It can range from silt and clay to large aggregates and construction debris.

From more detailed reports on specific sites (Golder, 1988; Golder 1989), contamination levels were found to be typical of soil contaminated with petroleum operations and spills. Oil and grease levels were measured up to 1,000 ppm, other organics up to 100 ppm and metals in the 100-500 ppm range (extreme of 17,800 ppm for lead). Inorganic remediation technologies would require in general

95% efficiency (not suitable, however, for "hot spots" of lead contamination). The same level of efficiency would be required also for treatment of organic contamination.

3.5 River Sediment

A comprehensive sediment quality assessment was done in 1985 (MOE, 1985) for the Toronto waterfront.

Humber Bay
Sediments located near the discharge of the Humber River are the most contaminated of the Humber Bay sediments: inorganics (chromium, copper, lead and zinc) are typically near 60 ppm (maxima to 200 ppm, extreme to 580 ppm). Total organic compounds (TOC) are typically 10-20 ppm.

Toronto Island and East Headland
The source of contaminants for the Island and East Headland area is the Main sewage treatment plant. This area is relatively clean, however, with some isolated contaminated spots: inorganics were measured near 150 ppm at a few locations.

Toronto Harbour
The Toronto Harbour includes the Island Waterways, the main harbour and the Keating Channel. Contamination levels by inorganics are typically 200 ppm.

River sediments would require a lower efficiency of treatment, since their levels of contamination are generally less than contaminated soils found in the GTA.

4. REVIEW OF CURRENT RESEARCH, DEVELOPMENT & DEMONSTRATION NEEDS

4.1 Current Research Programs in Ontario

Current research, development and demonstration (RD&D) projects in Ontario can receive governmental support from a number of different programs. These include:

a) Ontario's Environmental Research Program (Table 8)

the objective of the Environmental Research Program is to encourage excellence in environmental research by supporting research in priorities established by the Ministry of Environment and Energy's Research Advisory Committee.

b) Ontario's <u>Environmental Technologies Program</u> (Table 9)

the objective of the Environmental Technologies Program is to develop new technologies to overcome environmentally damaging practices. The program focuses on the latter stages of the technology innovation process, the development, refinement and commercialization of the process.

c) Environment Canada's <u>Contaminated Sediment Treatment Technology Program: CoSTTeP</u> (see Section 2.2, Table 10).

d) Canada-Ontario Agreement's <u>Great Lakes Cleanup Fund</u>.

e) CCME's <u>Development and Demonstration of Site Remediation Technology: DESRT</u> (see Section 2.2, Table 11).

f) <u>National Groundwater and Soil Remediation Program (GASReP)</u>, coordinated by WTC (Table 12).

These financial support programs usually have co-funding requirements between different levels of Canadian industries and governments, or even industry and government abroad. Activities also interrelate with the WTC's CoSTTeP program and the USEPA's SITE program (Table 13).

The majority of the soil remediation RD&D is done in conjunction with a private sector company which either has a technology they are promoting or the firm has a site that requires cleanup. Project areas also overlap in that the cleanup may be for the soil and/or the water at a site. The projects do, however, focus primarily on either the soil or the water.

Technologies being investigated cover the full range of chemical, physical and biological processes. In addition technologies are applied in-situ with the soil remaining in place or ex-situ with the soil having been removed from the ground. The same is true of contaminated water but ex-situ treatment is more common.

Types of treatments considered for funding or funded by each of the agencies noted above are presented in Tables 8 to 13. Specific data from each project are available from the funding organization or the private sector company.

4.2 Additional RD&D Needs

There is an appreciable amount of RD&D work being done in Ontario by private firms but most of it is concentrated in a few firms. Most of the University research projects are done by one institution. As a result, there is a great potential for other firms and universities to become involved with the development of soil remediation technologies.

Table 13 (listing US emerging technologies) illustrates the wide range of technologies that are being developed. The wide range also shows the benefit of a funding program dedicated to promoting RD&D in soil remediation (Lewis et al., 1992). Ontario's environment and green industry development could benefit from more emphasis being placed on hazardous waste treatment.

The overlap of financial support to the same companies for the same or related project shows a need for close coordination between the support agencies.

The primary area of emerging technology in the US is bioremediation. In view of the wide ranging temperature and soil conditions in Ontario that can affect the efficiency of this technology, it is recommended that research on applications of bioremediation also be emphasized here. To ensure that support does not duplicate USEPA efforts, it is recommended that impacts of cold weather and remote locations be the primary areas of research.

TABLE 13 (Continued)
SITE Emerging Technology Program Participants

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
University of South Carolina, Columbia, SC (E03)	In Situ Mitigation of Acid Water	Frank Caruccio 803-777-4512	Roger Wilmoth 513-569-7509	Acid Drainage	Most Metals	Not Applicable
University of Washington, Seattle, WA (E02)	Adsorptive Filtration	Mark Benjamin 206-543-7645	Norma Lewis 513-569-7665	Groundwater, Leachate, Wastewater	Metals	Not Applicable
Vortec Corporation, Collegeville, PA (E04)	Oxidation and Vitrification Process	James Hnat 215-489-2255	Teri Richardson 513-569-7949	Soil, Sediments, Mill Tailings	Metals	Most Organics
Warren Spring Laboratory, Hertsfordshire, United Kingdom (E04)	Physical and Chemical Treatment	Peter Wood 01-44-438-741122	Mary Stinson 908-321-6683	Soil	Metals	Petroleum Hydrocarbons, PAHs
Wastewater Technology Centre, Burlington, Ontario (E02)	Cross-Flow Pervaporation System	Rob Booth 416-336-4689 Chris Lipski 416-639-6320	John Martin 513-569-7758	Groundwater, Leachate, Wastewater	Not Applicable	VOCs, Solvents, Petroleum Hydrocarbons
Western Product Recovery, Group, Inc., Houston, TX (E04)	CCBA Physical and Chemical Treatment	Donald Kelly 713-493-9321	Joseph Farrell 513-569-7645	Wastewater, Sludges, Sediments, Soil	Heavy Metals	Most Organics
Western Research Institute, Laramie, WY (E01)	Contained Recovery of Oily Wastes	James Speight 307-721-2011	Eugene Harris 513-569-7862	Soil	Not Applicable	Coal Tar Derivatives, Petroleum Byproducts
Williams Environmental Services, Inc. (formerly Harmon Environmental Services, Inc.), Stone Mountain, GA (E01)	Soil Washing	Brett Burgess 404-879-4000	S. Jackson Hubbard 513-569-7507	Soil	Not Applicable	Heavy Organic Compounds

* Solicitation Number

TABLE 13 (Continued)
SITE Emerging Technology Program Participants

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Montana College of Mineral Science & Technology, Butte, MT (E05)	Campbell Centrifugal Jig	Theodore Jordan 406-496-4112	S. Jackson Hubbard 513-569-7507	Soil, Mine Tailings	Heavy Metals	Not Applicable
New Jersey Institute of Technology, Newark, NJ (E03)	GHEA Associates Process	Itzhak Gotlieb 201-596-5862	Annette Gatchett 513-569-7697	Mixtures	Most Inorganics	Most Organics
Nutech Environmental, London, Ontario (E05)	TiO_2 Photocatalytic Air Treatment	Brian Butters 519-457-2963	John Ireland 513-569-7413	Air	Not Applicable	VOCs
Nutech Environmental, London, Ontario (E04)	TiO_2 Photocatalytic Water Treatment	Brian Butters 519-457-2963	John Ireland 513-569-7413	Wastewater, Groundwater, Process Water	Cyanide, Sulphite, Nitrite Ions	PCBs, PCDDs, PCDFs, Chlorinated Alkenes, Chlorinated Phenols,
OHM Remediation Services Corporation, Findlay, OH (E05)	Oxygen Microbubble In Situ Bioremediation	Douglas Jerger 419-424-4932 Donald Michelson 703-231-5157	Ronald Lewis 513-569-7856	Groundwater	Not Applicable	Petroleum Hydrocarbons, Organic Solvents, Creosote, Pentachlorophenol
PSI Technology Company, Andover, MA (E04)	Metals Immobilization and Decontamination of Aggregate Solids	Srivats Srinivasachar 508-689-0003	Mark Meckes 513-569-7348	Soils, Sediments, Sludges	Heavy Metals, Volatile Metals	Most Organics
Pulse Sciences, Inc., San Leandro, CA (E04)	X-Ray Treatment	Randy Curry 510-632-5100	Esperanza Renard 908-321-4355	Soil, Water	Not Applicable	PCBs, TCE, TCA, Benzene
Purus, Inc., San Jose, CA (E04)	Photolytic Oxidation Process	Paul Blystone 408-453-7804	Norma Lewis 513-569-7665	Soil, Groundwater	Not Applicable	VOCs
Remediation Technologies, Inc., Seattle, WA (E05)	Methanotrophic Biofilm Reactor	Hans Stroo 206-624-9349	Kim Lisa Kreiton 513-569-7328	Gas	Not Applicable	Chlorinated Volatile Hydrocarbons
J.R. Simplot Company, Pocatello, ID (E03)	Anaerobic Biological Process	Dane Higdem 208-234-5367	Wendy Davis-Hoover 513-569-7206	Soil, Sludge	Not Applicable	Nitroaromatics
Trinity Environmental Technologies, Inc., Mound Valley, KS (E03)	Ultrasonically Assisted Detoxification of Hazardous Materials	Duane Koszalka 316-328-3222	Kim Lisa Kreiton 513-569-7328	Solids	Not Applicable	PCBs and Other Chlorinated Hydrocarbon Compounds
University of Dayton Research Institute, Dayton, OH (E05)	Photothermal Detoxification Unit (PDU)	Barry Dellinger 513-229-2846	Chien Chen 908-906-6985	Soil, Sludge, Aqueous Streams	Not Applicable	PCBs, PCDDs, PCDFs, Aromatic and Aliphatic Ketones, Aromatic and Chlorinated Solvents

TABLE 13 (Continued)
SITE Emerging Technology Program Participants

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
Groundwater Technology Government Services, Inc., Concord, CA (E04)	Below-Grade Bioremediation Cell	Ronald Hicks 510-671-2387	Ronald Lewis 513-569-7856	Soil, Sludge, Sediments	Not Applicable	Biodegradable Organic Compounds
Hazardous Substance Management Research Center at New Jersey Institute of Technology, Newark, NJ (E04)	Pneumatic Fracturing/ Bioremediation	John Schuring 201-596-5849	Uwe Frank 908-321-6626	Soil	Not Applicable	Biodegradable Organics
Institute of Gas Technology, Chicago, IL (E04)	Chemical and Biological Treatment	Robert Kelley 312-567-3[illegible]	Naomi Barkley 513-569-7854	Soil, Sludge, Groundwater, Surface water	Not Applicable	Most Organics
Institute of Gas Technology, Chicago, IL (E03)	Fluid Extraction-Biological Degradation Process	Robert Kelley 312-567-3809	Annette Gatchett 513-569-7697	Soil	Not Applicable	Most Organics
Institute of Gas Technology, Chicago, IL (E03)	Fluidized-Bed Cyclonic Agglomerating Incinerator	Amir Rehmat 312-567-5899	Teri Richardson 513-569-7949	Solid, Liquid, Gas	Not Applicable	Most Organics
IT Corporation, Knoxville, TN (E02)	Batch Steam Distillation and Metal Extraction	Robert Fox 615-690-3211	Ronald Lewis 513-569-7856	Soil, Sludge	Heavy Metals	Non-Specific Organics
IT Corporation, Knoxville, TN (E04)	Mixed Waste Treatment Process	Ed Alperin 615-690-3211	Douglas Grosse 513-569-7844	Soil	Non-Specific Inorganics	Non-Specific Organics
IT Corporation, Knoxville, TN (E02)	Photolytic and Biological Soil Detoxification	Robert Fox 615-690-3211	Randy Parker 513-569-7271	Soil	Not Applicable	PCBs, Other Non-Specific Organics
Membrane Technology and Research, Inc., Menlo Park, CA (E02)	VaporSep Membrane Process	Hans Wijmans or Vicki Simmons 415-328-2228	Paul dePercin 513-569-7797	Gaseous Waste Streams	Not Applicable	Halogenated and Nonhalogenated Compounds
Montana College of Mineral Science & Technology, Butte, MT (E03)	Air-Sparged Hydrocyclone	Theodore Jordan 406-496-4112	Eugene Harris 513-569-7862	Aqueous Solutions	Low-Concentration Metals	Not Applicable

* Solicitation Number

TABLE 13 Continued)

SITE Emerging Technology Program Participants

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
COGNIS, Inc., Santa Rosa, CA (E05)	Biological/Chemical Treatment	Jonathan Mielenz 707-576-6223	Naomi Barkley 513-569-7854	Soil	Heavy Metals	PAHs, Petroleum Hydrocarbons
COGNIS, Inc., Santa Rosa, CA (E05)	Chemical Treatment	Jonathan Mielenz 707-576-6223	Michael Royer 908-321-6633	Soil, Sediment, Sludge	Heavy Metals	Not Applicable
Colorado School of Mines, Golden, CO (E01)	Wetlands-Based Treatment	Thomas Wildeman 303-273-3642	Edward Bates 513-569-7774	Acid Mine Drainage	Metals	Not Applicable
Davy Research and Development, Limited, Cleveland, England (E04)	Chemical Treatment	Graham Wightman 01-44-642-607108	Kim Lisa Kreiton 513-569-7328	Soils, Sediments	Heavy Metals, Cyanides	Chlorinated phenols, Chlorinated solvents, Pesticides, PCBs
Electrokinetics, Inc., Baton Rouge, LA (E03)	Electrokinetic Remediation	Yaloin Acar 504-388-3992	Randy Parker 513-569-7271	Soil	Heavy Metals and Other Organics	Not Applicable
Electron Beam Research Facility, Florida International University and University of Miami, Miami, FL (E03)	High-Energy Electron Irradiation	William Cooper 305-348-3049	Franklin Alvarez 513-569-7631	Aqueous Solutions and Sludges	Not Applicable	Most Organics
Electro-Pure Systems, Inc., Amherst, NY (E02)	Alternating Current Electrocoagulation Technology	Thomas Stanczyk 716-691-2610	Naomi Barkley 513-569-7854	Groundwater, Wastewater, Leachate	Heavy Metals	Petroleum Byproducts, Coal-Tar Derivitaves
M.L. ENERGIA, Inc., Princeton, NJ (E05)	Reductive Photo-Dechlorination Treatment	Moshe Lavid 609-799-7970	Michelle Simon 513-569-7469	Liquid, Gas	Not Applicable	Volatile Chlorinated Wastes
Energy and Environmental Engineering, Inc., East Cambridge, MA (E01)	Laser-Induced Photochemical Oxidative Destruction	James Porter 617-666-5500	Ronald Lewis 513-569-7856	Groundwater, Wastewater	Not Applicable	Non-Specific Organics
Energy and Environmental Research Corporation, Irvine, CA (E03)	Hybrid Fluidized Bed System	D. Gene Taylor 714-859-8851	Teri Richardson 513-569-7949	Solids, Sludges	Volatile Metals	Most Organics
Enviro-Sciences, Inc., and ART International, Inc., Denville, NJ (E03)	Low-Energy Solvent Extraction Process	Werner Steiner 201-627-7601	S. Jackson Hubbard 513-569-7507	Soils, Sediments, Sludges	Most Inorganics	PCBs, Petroleum Hydrocarbons
Ferro Corporation, Independence, OH (E03)	Waste Vitrification Through Electric Melting	Emilio Spinosa 216-641-8580	Randy Parker 513-569-7271	Soils, Sediments, Sludges	Non-Specific Inorganics	Non-Specific Organics

TABLE 13

SITE Emerging Technology Program Participants [2]

Developer	Technology	Technology Contact	EPA Project Manager	Waste Media	Applicable Waste	
					Inorganic	Organic
ABB Environmental Services, Inc., Wakefield, MA (E03)*	Two-Zone Plume Interception In Situ Treatment Strategy	Sam Fogel 617-245-6606	Ronald Lewis 513-569-7856	Solids, Liquids	Not Applicable	Chlorinated and Nonchlorinated Solvents
Allis Mineral Systems, Inc. (formerly Boliden Allis, Inc.), Oak Creek, WI (E03)	Pyrokiln Thermal Encapsulation Process	John Lees 414-475-3862 Glenn Heian 414-762-1190	Marta Richards 513-569-7783	Soil, Sludge	Most Metallic Compounds	Most Organics
Aluminum Company of America (formerly Alcoa Separations Technology, Inc.), Pittsburgh, PA (E03)	Bioscrubber	Paul Liu 412-826-3711	Naomi Barkley 513-569-7854	Soil, Water, Air	Not Applicable	Most Organics
Atomic Energy of Canada, Limited, Chalk River, Ontario (E01)	Chemical Treatment and Ultrafiltration	Leo Buckley 613-584-3311	John Martin 513-569-7758	Groundwater, Leachate, Wastewater	Heavy Metals	Not Applicable
Babcock & Wilcox Co., Alliance, OH (E02)	Cyclone Furnace	Lawrence King 216-829-7576	Laurel Staley 513-569-7863	Solids, Soil, Liquids	Non-Specific Inorganics	Non-Specific Organics
Battelle Memorial Institute, Columbus, OH (E01)	In Situ Electroacoustic Soil Decontamination	Satya Chauhan 614-424-4812	Jonathan Herrmann 513-569-7839	Soil	Heavy Metals	Not Applicable
Bio-Recovery Systems, Inc., Las Cruces, NM (E01)	Biological Sorption	Tom Powers 505-523-0405	Naomi Barkley 513-569-7854	Groundwater, Leachate, Wastewater	Heavy Metals	Not Applicable
BioTrol, Inc., Chaska, MN (E03)	Methanotrophic Bioreactor System	Durell Dobbins 612-448-2515	David Smith 303-293-1475	Water	Not Applicable	Halogenated Hydrocarbons
Center for Hazardous Materials Research, Pittsburgh, PA (E03)	Acid Extraction Treatment System	Stephen Paff 412-826-5320	Kim Lisa Kreiton 513-569-7328	Soil	Heavy Metals	Not Applicable
Center for Hazardous Materials Research, Pittsburgh, PA (E04)	Lead Smelting	Steven Paff 412-826-5320	Patrick Augustin 908-906-6992	Battery Waste	Lead	Not Applicable
Center for Hazardous Materials Research, Pittsburgh, PA (E05)	Organics Destruction and Metals Stabilization	A. Bruce King 412-826-5320	Randy Parker 513-569-7271	Soil, Sediment	Heavy Metals	Non-Specific Organics

* Solicitation Number

(2) Source
The Superfund Innovative Technology Evaluation Program. Technology Profiles. 5th Edition. November, 1992.

TABLE : 12 DESCRIPTIONS OF GASReP PROJECT FOR 1992/93 *

#	TITLE	GOALS/SUMMARY OF PROPOSAL	PROPONENT(S)	COST/TIME $000 (years)
27	CO_2 Supercritical Fluid (SCF) Extraction of Soil Contaminated by Petroleum Hydrocarbons.	Determine the mass transfer coefficients and the distribution coefficients for oils and soil in SCF-CO_2 systems.	Warren Stiver University of Guelph	74.0 (3)
30	Bench-Scale Study of Off-Gas Treatment of Airborne Organic Volatiles Produced from Air-Stripping or Soil Venting of Petroleum Contaminated Soil Using Photo-oxidation Techniques.	Study destruction of airborne organic volatiles using advanced oxidation technique which combines the use of UV light and H_2O_2.	Carol Moralejo Wastewater Technology Centre	33.8 (0.25)
41	Aerobic Microbial Metabolism of Thiophenic Compounds Present in Petroleum.	Conduct laboratory experiments to investigate and understand microbial metabolism of several alkyl- and condensed thiophenes.	Phillip Fedorak University of Edmonton	47.6 (1)
47	Proposal to Demonstrate an Efficient Addition Technology for In Situ Bioremediation.	Demonstrate the value of injecting remedial solutions through a permeable wall ... to improve delivery of remedial solutions and efficient in situ bioremediation of BTEX.	J.F. Barker and R.W. Gillham Waterloo Centre for Groundwater Research	350.0 (2)
62	Proposed Study of the Behaviour and Remediation of LNAPL Gas Condensate Contamination in Heterogeneous and Fractured Bedrock and its Implications on Pump-and-Treat Remediation Methods.	Examine the field and pore-scale behaviour of LNAPL contamination in heterogeneous and fractured bedrock.	Paul Hardisty Piteau Engineering Ltd.	54.1 (n.a.)
84	Enhanced Biofiltration of Waste Off-Gas Streams.	Study the effects of various operating parameters associated with biofilters used to treat vapours from soil venting operations, and define attributes and constraints of this technology.	Henryk Melcer Wastewater Technology Centre	495.0 (3)

* CCIW's Groundwater and Soil Remediation Program

Table 11: CCME's DESRT Program Projects in Ontario

DEVELOPER	ACTIVITY/TECHNOLOGY
Ontario Ministry of the Environment	Clean-up of a tire fire site
Ontario Ministry of the Environment	Clean-up of a PCB spill site
Ontario Ministry of the Environment	Clean-up of an orphan hazardous waste disposal site
Ontario Ministry of the Environment	Groundwater treatment for arsenic contamination
Dearborn Environmental Engineering	Bioremediation of soils containing chlorinated phenols
EcoLogic International Inc.	Thermal/chemical reduction of high strength PCBs
Beak Consultants Ltd.	Anaeobic bioremediation of chlorinated organic compounds
Tallon Metal Technology Ltd.	Synthetic adsorbent for metals removal from harbour sediment

(FILE: GC:\TECH\SOILREM\0809TAB.DOC)

Table 10 (Continued):

Contaminated Sediment Treatment Technology Program (CoSTTeP)

Beak Consultants Ltd.	Sequential chemical leaching of metals from a river sediment
Sonofloc Environmental Technologies Ltd.	Ultrasonic flocculation of suspended solids
Tallon Metal Technologies Inc.	Acid solubilization of metals followed by chelation and separation for both river and harbour sediments
Waste Stream Technology Inc.	Ex-situ bioremediation of harbour sediment
Chemical Waste Management Inc.	Heat vapourization of organics followed by condensation

Table 10: Contaminated Sediment Treatment Technology Program (CoSTTeP)

DEVELOPER	TECHNOLOGY
Alteck Consulting Ltd.	Chemically assisted scrubbing followed by flotation separation of river sediment
Umatac Industrial Processing	Heat vapourization and cracking of organic contaminants in harbour sediments
Alberta Research Council	Coal stripping of hydrocarbons followed by flotation separation of harbour sediment
Bergmann USA Inc.	Soil washing of harbour sediment
BioGenesis Inc.	Chemically assisted soil washing
Cognis Inc.	Leaching and extraction of heavy metals from river sediment
Dearborn Environmental Engineering	Biological treatment through landfarming of hydrocarbons in harbour sediments
Derrick Environmental Services	Physical and chemical separation of river sediments
Ensotech Inc.	Chemical fixation of metals in a river sediment
EcoLogic International	Thermal reduction of harbour sediment organics
Institute of Gas Technology	Solvent desorption of organics from harbour sediments
Toronto Harbour Commissioners	Acidification/chelation/separation of heavy metals in harbour sediments
Siallon Technologies Inc.	Emulsification followed by solidification of hydrocarbons
SNC Lavalin Inc.	Chemical oxidation followed by biological treatment of organics in harbour sediments

Table 9: Ontario Environmental Technology Program Projects

DEVELOPER	TECHNOLOGY
EcoLogic International Inc.	Thermal/chemical reduction of harbour sediments
Trojan Technologies Inc.	Ultraviolet light destruction of organics
Tallon Metal Technologies Inc.	Synthetic adsorbent for metals recovery from soils
Dearborn Chemical Co. Ltd.	Bioremediation of soils containing chlorinated phenols
EcoLogic International Inc.	Thermal/chemical reduction of high strength PCBs
__________*	Contaminated site containment system
__________*	Pyrolysis of organic contaminants
__________*	Bioremediation of organic contaminated soils
__________*	Reductive dechlorination by bioremediation
__________*	In-situ oxidation of organic contamination followed by bioremediation

* Developer's name is confidential at time of report preparation as a contract to fund project has not been signed.

Table 8: Ontario Environmental Research Program Projects

DEVELOPER	TECHNOLOGY
Beak Consultants	Biodegradation of chlorinated solvents
University of Waterloo	Nutrient delivery for bioremediation of chlorinated solvents
Earth Science Association	Removal of organic contaminants from groundwater
Earth Science Association	Organic removal by overland flow of groundwater
Canviro Consultants Ltd.	Various treatment technologies for organics in soil
University of Guelph	Biosurfactants to remove organics from soil
University of Waterloo	Chemical oxidation of coal tar residuals
University of Guelph	Bioremediation of polychlorinated phenol
University of Guelph	Supercritical carbon dioxide extraction of petroleum compounds
Ecoplastics Ltd.	Retractable composite absorbents

Table 7: Ataratiri Site: Soil Quality (Organics)

CONTAMINANT	NUMBER OF SAMPLES	AVERAGE (ppm)	MINIMUM (ppm)	MAXIMUM (ppm)
Benzene	38	0.1	nd	0.8
Toluene	38	0.164	nd	0.9
Ethylbenzene	38	0.105	nd	0.367
Xylene	38	0.257	nd	1.3
Naphthalene	578	23.91	nd	7,966.7
Phenanthrene	578	13.25	nd	1,342
Pyrene	578	9.87	nd	648.1
PCDD/PCDF *	13	0.906*	nd	4.22*
PCBs	586	8.19	nd	2,252

*: expressed as 2,3,7,8-TCDD equivalents, in ppb.

Source: Ataratiri Soil Management Report. Volume 1 - Text. Report prepared by Trow, Dames and Moore for the City of Toronto Housing Department. August 1991.

Table 6: Ataratiri Site: Soil Quality (Inorganics)

CONTAMINANT	NUMBER OF SAMPLES	AVERAGE (ppm)	MINIMUM (ppm)	MAXIMUM (ppm)
Antimony	724	6	nd	400
Arsenic	745	13	nd	312
Barium	745	520	15	2,420
Berylium	745	3	nd	10
Cadmium	745	3	nd	60
Chromium VI Cr Total	713 745	0.14 60	0.024 1.19	5 1,420
Cobalt	745	14	nd	120
Copper	745	151	2	29,800
Cyanide (tot)	--	--	--	--
Lead	745	230	nd	14,000
Mercury	745	0.22	trace	17.4
Molybdenum	745	5	1	74
Nickel	745	59	nd	10,000
Selenium	745	0.6	0.08	6.8
Silver	745	2.7	nd	31
Zinc	745	349	14	18,900

Source: Ataratiri Soil Management Report. Volume 1 - Text. Report prepared by Trow, Dames and Moore for the City of Toronto Housing Department. August 1991.

Table 5: Soil Remediation Levels (Organics)
(all values in ppm)

CONTAMINANT	MOE[1] (Resident. Parkland)	MOE[1] (Commer./ Indust.)	CCME[2] (Resident Parkland)	CCME[2] (Commer./ Indust.)
Benzene	--	--	0.5	5
Chlorobenzene	--	--	1	10
Dichlorobenzene	--	--	1	10
Ethylbenzne	--	--	5	50
Styrene	--	--	5	50
Toluene	--	--	3	30
Xylene	--	--	5	50
Chloropenols	--	--	0.5	5
PAH	--	--	1	10
Naphthalene	--	--	5	50
Phenanthrene	--	--	5	50
Pyrene	--	--	10	100
Chlorinated aliphatics	--	--	5	50
Poly (3,4,5,6) chlorobenzenes	--	--	2	10
PCBs	--	--	5	50
PCDDs/PCDFs	--	--	0.001[3]	--

Note:

1) There are no cleanup levels for organics in the MOE guidelines. Source: Guidelines for the decommissioning and cleanup of sites in Ontario. Report prepared by Waste Management Branch, Ontario Ministry of the Environment. February 1989. PIBS 141E.

2) Source: Interim Canadian Environmental Quality Criteria for Contaminated Sites. Report CCME EPC-CS34, August 1991.

3) PCDDs and PCDFs expressed in 2,3,7,8-TCDD equivalents.

Table 4 : Soil Remediation Levels (Inorganics)
(all values in ppm)

CONTAMINANT	MOE[1] (Resident. Parkland)	MOE[1] (Commer./ Indust.)	CCME[2] (Resident Parkland)	CCME[2] (Commer./ Indust.)
Antimony	25	50	20	40
Arsenic	25	50	30	50
Barium	1,000 [3]	2,000	500	2,000
Beryllium	5 [3]	10	4	8
Cadmium	4	8	5	20
Chromium (VI) Chromium (total)	10 1,000	10 1,000	8 250	-- 800
Cobalt	50	100	50	300
Copper	200	300	100	500
Cyanide (tot)	--	--	50	500
Lead	500	1,000	500	1,000
Mercury	1	2	2	10
Molybdenum	5	40	10	40
Nickel	200	200	100	500
Selenium	2	10	3	10
Silver	25	50	20	40
Zinc	800	800	500	1,500

Note:

1) Criteria for Medium & Fine Textured Soils.
Source: Guidelines for the decommissioning and cleanup of sites in Ontario. Report prepared by Waste Management Branch, Ontario Ministry of the Environment. February 1989. PIBS 141E.

2) Interim remediation criteria for soils.
Source: Interim Canadian Environmental Quality Criteria for Contaminated Sites. Report CCME EPC-CS34, August 1991.

3) Provisional guidelines (guidelines are tentative: actual permissible levels in other situations may vary according to site-specific circumstances).

Toronto Harbor Commission (Toronto, Ont)	Soil recycling: soil washing, metal dissolution, chemical hydrolysis & biodegradation	- contam: inorganics, organics - efficiency: 75-82% (organics) for soil washing; 90% (light PAH) for chemical/biological treatment - cost: *
Wastech Inc (Oak ridge, TN)	Solidification and Stabilization	- contam: non specific inorganics, radioactives, non specific organics - efficiency: * - cost: *

*: data not available

Eli Eco Logic International Inc (Rockwood, Ontario)	Thermal Gas Phase Reduction Process	- contam: PCB, PAH, chlorophenols, pesticides - efficiency: 99.9999% PAH, PCB - cost: CDN $500/tonne
EmTech Environmental Services (Fort Worth, TX)	Chemical Treatment and Immobilization	- contam: heavy metals, non-specific organics - efficiency: leachate (TCLP) reduction by 100x or more. - cost: *
ENSITE Inc (Tucker, GA)	Biotreatment Process (SafeSoil)	- contam: petroleum HC, TCE, PAH, aliphatic solvents - efficiency: 86% (PAH), 99.5% (TCE) - cost: US $50-100/cu. yard
NOVATERRA Inc (formerly Toxic Treatments USA Inc) (Torrance, CA)	In Situ Steam and Air Stripping	- contam: VOCs, SVOCs - efficiency: VOC (85%), SVOC (55%) - cost: US $100-300/cu. yard
Risk Reduction Engineering Laboratory (Cincinnati, OH)	Base-catalysed dechlorination process	- contam: PCB, PCP - efficiency: 99.9999% (PCB) - cost: US $245/ton
SBP Technologies Inc (Stone Mountain, GA)	Membrane Separation	- contam: PAH, PCB, TCE, organic compounds - efficiency: 95% (PAH), 25-30% (smaller phenolics) - cost: *
Silicate Technology Corporation (Scottsdale, AZ)	Solidification and Stabilization Treatment Technology	- contam: metals, cyanide, ammonia, heavy organics - efficiency for TCLP only: PCP (97%), arsenic (92%), chromium (54%), copper (90%) - cost: US $200/cubic yard
SoilTech ATP Systems Inc (Englewood, CO)	Anaerobic Thermal Processor (thermal desorption)	- contam: PCB, VOC, chlorinated pesticides, VOCs - efficiency: PCB (99.99%), VOC/SVOC (no TCLP leachate) - cost: US $120/300/ton
Soliditech Inc (Houston TX)	Solidification and Stabilization	- contam: metals, non-specific organics - efficiency: TCLP metals not detected, VOC detected - cost: US $152/cubic yard
Terra Vac Inc (San Juan, Puerto Rico)	In Situ Vacuum Extraction	- contam: VOC and SVOC - efficiency: 92% in sandy soils, 90% in clays - cost: typically US $40/ton, range 10-150 depending on gas elluent and wastewater treatment requirements

Table 3: SITE (USEPA) Demonstrated Processes

DEVELOPER	TECHNOLOGY/PROCESS	COMMENTS
AWD Technologies Inc (San Francisco)	Integrated Vapor Extraction and Steam Vacuum Stripping (AquaDetox) In-situ operation	- contam.: VOC (6000 ppm), TCE, PCE - efficiency: * - cost: US $20-50/cu.yard
BioTrol Inc (Chaska, MN)	Soil Washing System	- contam.: PAH, PCP, petroleum hydrocarbons, pesticides, PCB, industrial chemicals, metals - efficiency: 88-94% - cost: US $168/ton
Bioversal USA Inc (Des Plaines, IL)	BioGenesis Soil Cleaning Process (complex surfactant and water)	- contam: vol./non-vol. oils, chlorinated HC, pesticides, heating oils, diesel fuel, gazoline, PCB, PAH - efficiency: 95-99% HC (up to 15,000 ppm); sequential washes up to 50,000 ppm - cost: CND $60-100/tonne
CF Systems Corporation (Waltham, MA)	Solvent extraction (liquified gases: propane)	- contam: VOC, PCB, dioxins, PCP, refinery wastes - efficiency: 90-98% (sediments 360-2575 ppm PCB) - cost: PCB (US $150-450/ton), relative to job size
Chemfix Technologies Inc (Metairie, LA)	Solidification and stabilization (mobility reduction)	- contam: heavy metals, high MW organics - efficiency: leachate reduced by 94-99% - cost: US $73/ton
Chemical Waste Management Inc (Geneva, IL)	X-TRAX process (thermal desorption)	- contam: VOC, SVOC, PCB - efficiency: VOC (LT 1ppm), SVOC (LT 10-1 ppm), 120-6000ppm PCB reduced to 2-25ppm - cost: US $150-250/ton
Dehydro-Tech Corporation (East Hanover, NJ)	Carver-Greenfiled Process (extraction of oil-soluble contaminants)	- contam: PCB, PAH, dioxin, oil-soluble organics - efficiency: below TCLP limits (leachate) - cost: US $10-300/ton (site specific)
Ecova Corporation (Redmond, WA)	Bio-slurry Reactor	- contam: PAH, creosote mostly - efficiency: 89% (2 weeks), 93% (12weeks) - cost: *

Table 2: CoSTTeP Demonstrated Processes

DEVELOPER/SITE	TECHNOLOGY/PROCESS	STATUS
Bergmann USA Inc (Toronto's Inner Harbour)	Water based soils washing (pre-treatment to SNC Bioslurry or Metanetix Process)	- Pilot-scale test done at Toronto Harbour - efficiency: 99% in soil - cost: CND $50-75 US/tonne
Dearborn Environmental Consulting Group (Hamilton Harbour)	DEARBORN Bioremediation	- contaminants: PAH, chlorophenols, pesticides - efficiency: 90-99% (depending on initial concentration) - cost: *
Derrick Environmental Services Corp. (Sediment from Welland River)	Derrick Solid/Liquid Separation Technology	- pilot-scale project completed Nov. 91 (Welland, Ont.) - efficiency: screening & separation system only - cost: *
Eli Eco Logic International Inc.(Hamilton Harbour)	EcoLogic Thermal Destructor (high temperature thermo-chemical reduction)	- contaminant: PCB - efficiency: (99.9999% PCB on bench-scale - cost: CND $500 /tonne
DeVoe Environmental Lab. (Toronto Harbour Comm.)	Metanetix Technology (metal extraction)	- contaminants: heavy metals - efficiency: 95% - cost: *
SNC Lavalin Inc (Toronto Harbour)	SNC Bioslurry Process (biological treatment)	- contaminants: oils, MAH, PAH (pretreatment required for screening and metal extraction) - efficiency: * - cost: CND $50-100/tonne
Tallon Metal Technologies Inc (Hamilton Harbour, Welland River)	VITROKELE Technology (metal extraction)	- contaminants: inorganics - efficiency: 99.9 % of leachable metals - cost: CND $50-150/tonne

*: data not available

Table 1: DESRT Demonstrated Processes

PROJECT SITE	TECHNOLOGY/PROCESS	STATUS
Canada Creosote (Calgary, Alb.)	Soil washing of river-bed gravel	- On-site pilot test completed in 1991 - efficiency: * - cost: *
Dearborn Environmental (Trenton, Ont.)	Native bacteria biodegradation	- Domtar Inc.'s wood treatment facility: PCP soil contamination - Schedule: Sept.91 - Fall'92 - efficiency: * - cost: *
Tallon Metal Technologies Inc. (Toronto, Ont.)	"Vitrokele" process (absorbent)	- Heavy metal contaminants from lake sediment (Toronto Harbour) - efficiency: * - cost: *
Biogenie Inc (Quebec City, Que.)	Enhanced bioremediation	- 500-tonne petroleum contaminated soil - efficiency: * - cost: *
Vidangeur de Montreal Ltee (Montreal, Que.)	PYROVAC (vacuum pyrolysis)	- petroleum, chlorinated solvent contaminated soils - efficiency: * - cost: *
Ville Mercier (Que.)	Soil washing (surfactants)	- site contaminated with HC and chlorinated organics - efficiency: * - cost: *
Dept. of Transportation (Saint John, NB)	Washing and bioslurry reactor treatment	- PCB and heavy metals contaminated soil - efficiency: *) - cost: *

*: data not available

USEPA, 1991b
Guide for conducting treatability studies under CERCLA. Soil washing: interim guidance. EPA/540/2-91/020A. PB92-170570. September 1991.

USEPA, 1992a
SITE Demonstration Bulletin. Soil recycling treatment train. The Toronto Harbour Commissioners. EPA/540/MR-92/015, November 1992.

USEPA, 1992b
The Superfund Innovative Technology Evaluation Program: technology profiles. Fifth Edition. EPA/540/R-92/077, November 1992.

VISITT, 1992a
Vendor Information System for Innovative Treatment Technologies (VISITT). User manual (VISITT Version 1.0), USEPA, Office of Solid Waste and Emergency Response, Technology Innovation Office. EPA/542/R-92/001. June 1992.

VISITT, 1992b
Vendor Information System for Innovative Treatment Technologies (VISITT). Database available on LAN (Waste Management Branch). Updated March 1992.

WTC, 1992
Sediment Treatment technologies database (SEDTEC). Produced by Wastewater Technology Centre, Burlington, Ontario. Update December 26, 1992.

(File: GC:\TECH\SOILREM\0809TEX.DOC)

REFERENCES

Beak, 1990
Strategy for the decommissioning of soils in the Port Industrial District, Toronto, Ontario. Report prepared for the Toronto Harbour Commissioners by Beak Consultants Limited, September 1990.

Beak, 1992
A survey of microbial inoculants for bioremediation and identification of information requirements suitable for the feasibility evaluation and validation of bioremediation. Prepared for Hazardous Contaminants Branch, MOEE by Beak Consultants Limited. ISBN 0-7778-0322-4. PIBS 2152. November 1992.

CCME, 1991
Interim Canadian Environmental Quality Criteria for Contaminated Sites. Canadian Council of Ministers of the Environment (CCME). Report CCME EPC-CS34, August 1991.

CCME, 1992
The national contaminated sites remediation program: 1991-1992 annual report. The Canadian Council of Ministers of the Environment, CCME-EPC-NCSRP 52 E/P, ISBN 0-919074-92-8.

Golder, 1988
Testing of specific organic compounds in subsurface soils: EPC Ashbridges Bay Property, Toronto. Report prepared by Golder Associates to Esso Petroleum Canada. January 1988.

Golder, 1989
Management information strategy: Toronto terminal, Commissioners Street site, Toronto. Volume 2: appendices. Report to Texaco Canada Inc. by Golder Associates, SENES Consultants, ZENON Environmental Inc. and The Proctor & Redfern Group. January 1989.

Kendall, P.R.W., 1991
Identification of potential environmental and health concerns of soil remediation technologies. Environmental Protection Office, Department of Public Health, City of Toronto, November 1991.

Lewis, N.M., N.P. Barkley and Tracie Williams, 1992
1992 Update of U.S. EPA's Superfund Innovative Technology Evaluation (SITE) Emerging Technology Program. J.Air Waste Manage. Assoc., Vol. 42, No. 12 (December 1992), pp 1644-1656.

MOE, 1985
Historical development and quality of the Toronto waterfront sediments - Part 1. Report prepared by Water Resources Branch, Ontario Ministry of the Environment. May 1985. ISBN 0-7729-0493-6.

MOE, 1988
Thirty seven municipal water pollution control plants: pilot monitoring study. Volume I: interim report. Volume II: Appendix A. Prepared by Canviro Consultants for Water Resources Branch, MOE. December 1988.

MOE, 1990
Guidelines for the decommissioning and cleanup of sites in Ontario. Report prepared by Waste Management Branch, Ontario Ministry of the Environment. May 1990.

MOE, 1992
Remediation technologies for contaminated soils. Report prepared by Technology & Site Assessment Section, Waste Management Branch, Ontario Ministry of the Environment. ISBN 0-7778-0323-2. PIBS-2157. October 1992.

Hill, Ronald D. and Robert A. Olexsey, 1991
Overview of the Superfund Innovative Technology Evaluation (SITE) program. Preprint series (RS-16), pp. 2-7. The EPA SITE program: innovative remediation technologies for hazardous wastes sites. Journal of the Air & Waste Management Association, 1991.

USEPA, 1986
Superfund Innovative Technology Evaluation (SITE) strategy and program plan. United States Environmental Protection Agency (USEPA). EPA/540/G-86/001, OSWER 9380.2-3, December 1986.

USEPA, 1989a
The Superfund Innovative Technology Evaluation Program: technology profiles. EPA/540/5-89/013, November 1989.

USEPA, 1989b
Guide for conducting treatability studies under CERCLA, interim final. EPA/540/2-89/058, 1989.

USEPA, 1991a
The Superfund Innovative Technology Evaluation Program: technology profiles. Fourth Edition. EPA/540/5-91/008 November 1991.